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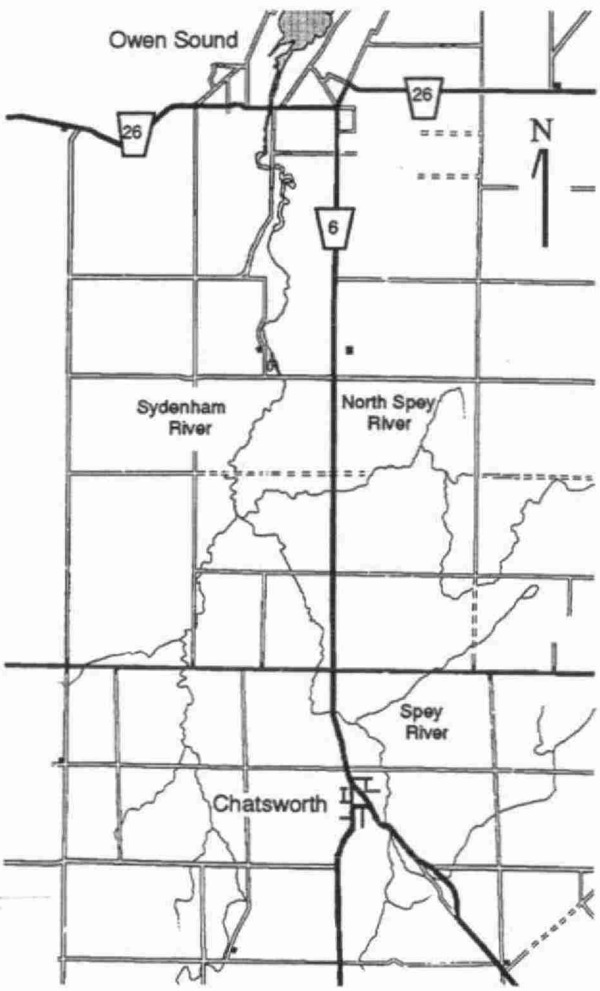
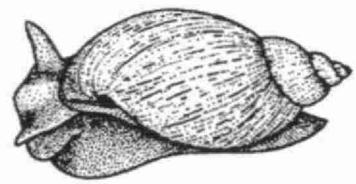
Southwestern Region
Water Resources Assessment Unit
985 Adelaide St. South
London, Ontario N6E-1V3

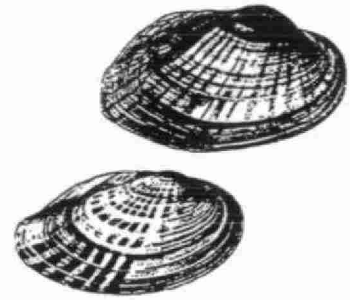
BioMAP: Concepts, Protocols and Sampling Procedures for the Southwestern Region of Ontario

by

Dr. Ronald W. Griffiths







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BioMAP:
Concepts, protocols and sampling procedures for the Southwestern Region of Ontario

1. Introduction:

Data collection through time (i.e. monitoring) by environmental agencies is essential to understand and manage aquatic ecosystems. Without monitoring, these organizations are essentially blind and have little ability to anticipate water quality degradation of unimpaired aquatic systems, to quantify water quality improvements resulting from costly abatement programs or to document trends in the state of the environment.

In Ontario, the Ministry of the Environment and Energy (MOEE) has the legislative mandate through the Ontario Water Resources Act and the Environmental Protection Act to manage the water resources of the Province and protect its quality. The MOEE operates the Provincial Water Quality Monitoring Network (PWQMN), a monitoring program that currently measures 16 water chemical and 4 bacteriological variables from monthly water samples to estimate water quality conditions at about 700 sites throughout the Province. Concerns, however, have been raised that the PWQMN is too narrowly focused, particularly when assessing water quality conditions in the southern region of the Province. Routine chemical analyses of water are known to be unreliable predictors of ecosystem health (EPA 1985). Impacts on water resources resulting from channelization, flow and temperature alterations or physical habitat destruction for example are typically undetectable by chemical monitoring programs (e.g. Dean and Burlington 1963; Henderson 1949). The U.S. Fish and Wildlife Service noted that 49% of impaired stream segments were related to physical habitat degradation, while 67% were related to flow alterations, neither of which are treated by U.S. Environmental Protection Agency (EPA) programs (Judy et al 1984). The continuing decline in the quality of American water resources despite massive U.S. regulatory efforts indicates the inadequacies of programs that rely on chemical monitoring and control approaches to protect water resources (EPA 1987, 1988 a,b, 1989a, 1990; General Accounting Office 1987; National Resource Council 1987).

Several problems limit the usefulness of chemical measurements as early warning indicators of water quality impairment:

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i) it is impractical to continuously monitor at all times, and thus spills and aperiodic events may go undetected;
ii) all potentially toxic chemicals are not measured or not known;
iii) knowledge of chemical concentrations in water does not always provide an accurate picture of biological availability;
iv) toxicological information is unavailable for many chemicals;
v) chemicals may interact with each other and with other environmental factors (e.g. hardness, pH, temperature) that alter their biological effect;
vi) substantial biological impact may occur before toxic chemicals reach detectable concentrations;
vii) impacts may be caused by physical factors (e.g. temperature, flow, channelization) and thus go undetected.

Because water pollution is defined by its affect on living organisms, assessment of water quality must principally be through biological measures. Biological responses integrate the independent and interactive effects of environmental stressors and factors, a property that makes them more robust indicators of ecosystem health than the concentrations and loadings of individual chemicals. Furthermore, the use of *in situ* organisms circumvents the need for any information or assumptions about the toxicity of chemicals to surmise their effects on aquatic life. Aquatic organisms, therefore, can be used to directly measure the effects of environmental stresses on aquatic systems, regardless of their frequency or intensity. Studies of population dynamics, food-web organization, and taxonomic structure of *in situ* biological communities have been much more successful at predicting the effects of anthropogenic stress on aquatic systems than single-species bioassays, complicated modelling or impact-statement approaches, which have been singularly unsuccessful (Schindler 1987).

Concerns about the limitations and usefulness of chemical indicators has resulted in a shift by many environmental agencies away from a sole reliance on chemical monitoring to an approach that includes biological monitoring. The Canadian Federal Government has recently made biological monitoring a component of the Environmental Effects Monitoring requirement in the amended Pulp and Paper Effluent Regulations of the Fisheries Act, mandatory for all Canadian pulp and paper mills discharging effluent into aquatic environments (EC 1991a). In the United States, the Environmental Protection Agency has continuously increased the role of biological monitoring throughout the 1980s by calling for:

i) coordination of biological sampling with chemical sampling (EPA 1984);
ii) inclusion of biological criteria in its water quality standards program (EPA 1988a);
iii) restructuring of existing monitoring programs to document the impact of regulatory programs (EPA 1989);
iv) the incorporation of good science at all levels of water resource policy (EPA 1988b, 1989);and
v) adoption of narrative biological criteria into water quality standards during the 1991-1993 triennium (EPA 1990).

Some U.S. State Governments have already adopted legal biological criteria (Florida, Vermont), biologically-based use designations (Maine, Arkansas), or biological criteria for assessment and monitoring (Colorado). Ohio is incorporating biological monitoring into regulations for attainment of goals set out in the Clean Water Act.

Provincial laws in Ontario concerning water quality do stress a biological, not chemical, basis for impairment. The Ontario Water Resources Act states that:

> the quality of water shall be deemed to be impaired if,notwithstanding that the quality of the water is not or may not become impaired, the material discharged or caused or permitted to be discharged or any derivative of such material causes or may cause injury to any person, animal, bird or other living thing as a result of the use or consumption of any plant, fish or other living matter or thing in the water or in the soil in contact with the water;

while the Environmental Protection Act defines "adverse impact" to include:

> i) impairment of the quality of the natural environment for any use that can be made of it,
> ii) injury or damage to property or to plant or animal life,
> iii) an adverse effect on the health of any person,
> iv) rendering any property or plant or animal life unfit for use by man.

Thus in 1992, the **Bio** logical **M**onitoring and **A**ssessment **P**rogram (BioMAP) was developed to complement the current PWQMN and thus provide a more holistic environmental monitoring system for the management of Ontario's water resources. This report provides an outline of BioMAP as implemented by the Water Resources Assessment Unit, Southwestern Region of MOEE beginning in April of 1993.

2. Biological Monitoring Concepts:

Biological monitoring, for the context of BioMAP, is the temporal sampling of *in situ* (ambient) biota occurring at a site in an aquatic system (river, lake, wetland) for the purpose of assessing water resource quality. Water quality is defined as the ability of aquatic systems to support life; it is not restricted to the chemical composition of water.

Macrophytes, algae, benthic invertebrates, and fishes are the four groups of biota that are typically utilized in biological monitoring programs. Benthic macroinvertebrates (e.g. insects, crustaceans, snails, bivalves, worms, and leeches), however, have been the most widely utilized group of organisms to assess water quality, particularly after the publication of "The Biology of Polluted Waters" by H.B.N. Hynes in 1960. The Biological Survey Program of the former Ontario Water Resources Commission, which began in 1964, used benthic macroinvertebrates to assess the water quality of numerous streams and rivers throughout Ontario (Johnson 1967).

Benthic macroinvertebrates provide an excellent means for evaluating local water quality conditions because:

i) they are abundant in all types of aquatic systems, living on or in the substrate;
ii) they are easily collected with relatively inexpensive gear;
iii) they are readily identified;
iv) they usually remain in a localized area because of their restricted mobility and habitat preference;
v) they are continuously subjected to the full rigor of the local environment throughout their aquatic life-cycle, which may vary from weeks to years;
vi) they show a wide range of tolerances to various degrees and types of pollution;
vii) they integrate the effects of all pollutants and environmental conditions over time and thus provide a holistic measure of ecological impact.

Although benthic invertebrates have little social relevance, they are an important food source for fish and waterfowl, organisms that the public relate with unpolluted environmental conditions. Furthermore, historical macroinvertebrate data are available for many streams, rivers and lakes throughout the Southwestern Region of Ontario.

Benthic macroinvertebrates are the primary group of organisms used for BioMAP, although other groups of organisms may be required in specific circumstances to assess water quality. Benthic macroinvertebrates are those larger organisms that inhabit the bottom substrates (e.g. sediments, debris, snags, aquatic plants, filamentous algae) of aquatic habitats for at least part of their life cycle, although surface-dwelling (neuston) and swimming (nekton) species are frequently included. As a general guideline, macroinvertebrates include those species whose body width exceeds 500 μm. at some time during its life cycle. Typically this fauna includes aquatic insects (e.g. stoneflies, mayflies, caddisflies, beetles, bugs, true flies), crustaceans (e.g. isopods, amphipods, crayfishes), molluscs (e.g. snails, clams, mussels), annelids (e.g. leeches, oligochaetes), and a few other groups (e.g. proboscis worms, flatworms).

3. BioMAP Protocol for the Southwestern Region of Ontario

a) Program Description:

Forty biological sampling sites are currently allocated to BioMAP for the Southwestern Region of MOEE. Because flowing-water environments predominate the aquatic systems within this area of Ontario, all these sites are located on streams and rivers.

Ten BioMAP sites are allocated to determine "benchmark" water quality conditions across the Region (Table 1; Fig. 1). These selected sites are situated at locations that have little possibility of upstream land-use change over the next 10 years. Ideally, these sites would have been located on streams draining undisturbed (natural) terrestrial ecosystems. Unfortunately, these ecosystems have long since been replaced by agri-systems in the southern half of the Region and thus the more southerly sites reflect benchmark conditions (i.e. best water quality conditions currently available) as opposed to reference conditions (i.e. unimpaired water quality conditions). The 10 sites encompass a diverse array of habitats, e.g. small streams and large rivers, cold and warm water streams. They are sampled twice a year, in mid-spring (May) and early autumn (October). In addition to providing current water quality conditions at 10 sites, data from these benchmark sites provide information on the best water quality conditions available in the different areas of the Region, water quality characteristics of unimpaired systems (northern sites), a measure of temporal (seasonal and annual) variation, a measure of spatial variation between similar habitats and a measure of long-term trends in water quality across the Region. This information will be

invaluable for scientific environmental assessments conducted throughout the Region. Relocation of these stations will be considered about every 10 years.

A second set of 10 BioMAP sites are utilized as "early warning indicators" of water quality degradation (Table 1; Fig. 1). These sites are placed downstream of areas that are likely to undergo a land-use change in the near future (1-5 years). These sites provide a direct measure of environmental stress resulting from various types of land-use change (e.g. agriculture, urbanization, deforestation, rural residential construction). Half of the sites are sampled in mid-spring while the remainder are sampled in early autumn. Relocation of these stations will be considered about every 5 years.

A third set of 10 BioMAP sites are utilized to provide a quantitative measure of water quality improvement or "reclamation" resulting from remedial measures (Table 1; Fig. 1). These sites are located downstream of areas that are or will shortly be undergoing remediation (e.g. reforestation) or abatement work (e.g. sewage treatment plant upgrading). These sites provide a direct measure of the water quality benefits from various types of remedial activities. Half of the sites are sampled in mid-spring while the remainder are sampled in early autumn. Relocation of these stations will be considered about every 5 years.

The final 10 BioMAP sites are allocated to "special projects". These stations will provide the Region with the flexibility necessary to deal with specific environmental problems and questions. For example, they may be used to examine the effect of a specific pollutant on water quality (e.g. the effect of nitrate from septic tank systems on water quality), the effect of a specific practice on water quality (e.g. effect of no till farming on water quality), the effect of land-use change on water quality or to collect water quality information from a specific drainage basin. These sites are sampled anytime during the year, although the spring and autumn seasons are preferred and are typically relocated every year. In 1993, several BioMAP sites will be located along the Teeswater River in the vicinity of the village of Teeswater and along Mill Creek near the Pt. Elgin landfill site. Both of these studies will be assessing the effects of specific discharges on water quality.

b) Field Sampling Methods and Procedures:

Two quantitative samples and a single qualitative sample are collected at each site. The purpose of the quantitative samples is to provide an estimate of the density (number of organisms

per unit area) of each taxon that occurs in the sampled habitat. The type of equipment required to quantitatively sample the benthic macroinvertebrate fauna depends on the specific habitat available in the stream reach. A Surber or T sampler is used in shallow, fast-flowing, gravel bottom reaches (riffle or erosional habitats) of streams and medium-sized rivers; an Ekman grab is used in deeper, slow-flowing, muddy reaches (pools or depositional habitats) of rivers, while a Ponar grab is used to sample larger rivers with heterogeneous substrates (Fig. 2). Each of these samplers encloses a specific area of the stream bottom from 0.05 to 0.1 m^{-2}. All organisms within this area are collected. Whenever possible, efforts are made to select a size of sampler that will yield 200-400 macroinvertebrates (a minimum of 100) from the enclosed sampling area.

Artificial substrates are used when the habitat is extremely heterogeneous or cannot effectively be sampled with the equipment mentioned above. They consist of cubed-shaped, wire baskets filled with cobble-sized substrate. The cages are placed into the stream, secured by stakes, and recollected after 6 weeks. All organisms within the cage are collected.

Riffles are the preferred sampling habitat for the quantitative samples. Presently, riffles are sampled at all Benchmark, Early Warning and Reclamation sites using either a Surber and T-sampler. In the near future, the Surber sampler will be phased out and the T-sampler (sampling area = 0.05 or 0.10 m^{-2}) will become the primary sampler for the program.

The purpose of the qualitative sample is to provide an estimate the total species richness (number of different taxa) that occurs in a reach (about 5-10m section) of the river. Qualitative samples are typically collected with a hand sieve, although additional equipment is used depending on habitat characteristics; D-frame nets (Fig. 2) will be used in addition to hand sieves at all sites starting in 1994. Generally, 15 (small streams) to 30 (larger rivers) minutes are spent sampling the various habitats represented in the stream reach. The length of time spent collecting invertebrates and the various habitats searched (e.g. sand, gravel, wood, undercut banks, large rocks, aquatic vegetation, filamentous algae) are recorded in the field notes.

Mesh size for collecting nets range between 590 and 600 μm because the primary purpose of this program is to assess local water quality conditions, not to provide an inventory of all species in the stream. A mesh size of 600 μm assures that at least 90% of the macroinvertebrate biomass will be collected at a site 95% of the time. The mesh size of all processing equipment (i.e. sieves) is 500 μm, to assure that all organisms with a maximum preserved body width of at

least 600 μm are retained in the sample; an especially important precaution when the organisms are handled live (e.g. during sorting).

The macroinvertebrates in each sample are generally sorted live from the debris in the field, identified to family, enumerated and placed in bottles filled with 80% ethanol. Field sorting provides real-time environmental quality assessment. If samples are preserved in the field (10% buffered formalin or 80% ethanol), rose bengal stain and low-power magnification (6x lense) are used to aid in sorting the invertebrates from the debris. A BioSurvey Card (Fig. 3) recording the above mentioned data is completed for each sample.

Careful recording of field data and observations is as critical to the proper interpretation of the biological data in terms of water quality as the collection of representative samples. A standardized field note form is completed at each site which forces the field staff to record essential data about the site is general (front leaf) and about the samples specifically (back leaf) (Fig. 4). A camera is used to take colour slides of the general area (e.g. surrounding land-use, riparian vegetation, stream site) and specific characteristics of the stream reach (e.g. bottom sediments, representative stream habitats, sampling locations). A 5-10 minute video record of the general area and the specific characteristics of the stream reach is also made. Whenever possible, the person interpreting the benthic invertebrate data is a member of the field collection staff.

c) Sub-sampling:

Sampling a smaller area (minimum of 0.05 m^{-2}) is the preferred method of reducing the total number of macroinvertebrates in a sample to between 200 and 400. However, when the abundance of macroinvertebrates in a sample is preceived to be >600 then the sample is generally subsampled to reduce sorting time using the following procedure:

1. A series of sieves (e.g. 8mm, 4mm, 2mm, 1mm, 500μ) is stacked in order of mesh size (8mm mesh sieve on top, 500μ mesh sieve on bottom of stack);
2. The sieve stack is placed in a sink or on a well-drained area of ground and the benthic sample is slowly poured over the entire area of the top sieve;
3. Two to four sample volumes of water are poured over the entire area of the top sieve and then the stack is gently shaken to drain off as much water as possible;
4. All macroinvertebrates are sorted from the debris in the coarse (8mm, 4mm) sieves and place into a labelled bottle. A tag recording that the complete sieve sample was sorted is put in the bottle;

5. If the number of macroinvertebrates in the 2mm sieve is perceived to be greater than 200, then place the complete sample onto a balance;
6. The sample is mixed and a portion is removed from the balance estimated to contain at least 100 individuals (e.g. 1/2, 1/3, 1/4, 1/5), the weight of the removed fraction is recorded and the invertebrates sorted from the debris and placed into a new labelled bottle;
7. If 100 organisms are not picked from the sieve sample, then another fraction is removed from the sieve sample, the weight of the removed fraction recorded and the organisms sorted from the debris and placed into the bottle. This procedure is repeated until at least 100 organisms are collected, then the total weight of the sorted fraction and the total weight of the sieve sample is recorded on a tag and placed in the bottle;
8. If the number of macroinvertebrates in the 1mm sieve is perceived to be greater than 200, then the complete sample is placed onto a balance and steps 6 and 7 repeated. NOTE: Start with about half the weight taken from the 2mm sieve to obtain 100 organisms. All organisms sorted from the debris in the 1mm sieve are placed into a new labelled bottle, the total weight of the sorted fraction and the total weight of the sieve sample are recorded on a tag and placed in the bottle;
9. Step 8 is repeated for the 500µ mesh sieve sample; Note: The samples in all sieves are kept moist and not allowed to dry.
10. Shade the top eighth of the caps on all bottles that contain invertebrates from subsampled sieve fractions. A separate BioSurvey Card is made for each subsampled sieve fraction. The weight of the sieve fraction sorted and the total weight of the sieve sample is recorded on the card.

Filamentous algae frequently collects in the 2mm sieve. In samples where this type of algae is abundant:

1. The complete sample is washed from the sieve into a white enamel tray;
2. The algal mass is gently pulled apart by hand to separate the organisms from the algae;
3. The complete sample is poured back through the sieve series (2mm, 1mm, 500µ);
4. Steps 1 through 3 are repeated as needed (2 or 3 times typically).

Using the subsampling procedure when necessary, the collection and processing time of a quantitative sample is under 3 person-hours.

d) Taxonomic identification:

The identification and enumeration of benthic macroinvertebrates provides the foundation for water quality assessment. BioMAP assesses water quality utilizing the following macroinvertebrate groups: insects (e.g. stoneflies, mayflies, caddisflies, beetles, bugs, true flies), crustaceans in the isopod, amphipod, crayfish and shrimp families, molluscs (e.g. snails, clams, mussels), annelids in the leech and oligochaete families, and flatworms. Furthermore, only those individuals with a maximum body width >500μm are identified and reported. Organisms with a body width <500μm are removed because the sampling equipment retains only a small proportion of benthos in this size category.

Genus is the basic taxonomic level for identifications. The decision to identify individuals of a specific group to a taxonomic level other than genus is based on the ecological and taxonomic knowledge of the group and the ease of identification. If species within a genus (i.e. congeneric species) are known to show a wide range of tolerances to different environmental conditions and stresses (e.g. *Stenonema* , *Baetis*), then identification of late instars (nymphs) or adults to species is desirable, and if good taxonomic keys and species descriptions are available, then identification to species is conducted. For the few taxonomic groups that have been poorly studied or are difficult to identify (e.g. flatworms), a broader taxonomic level (family, order) is used. Table 2 provides the present level of taxonomic resolution for the various macroinvertebrate taxa and core taxonomic references (keys). More precise identification of individuals is often done in order to improve the ecological knowledge and geographic distribution of macroinvertebrates. However, only the taxonomic resolution noted in Table 2 is used for water quality analyses. This provides for a standardized basis so that water quality results from across southwestern Ontario can be compared and related.

As our taxonomic and ecological knowledge of macroinvertebrates increases, it will be necessary to review and periodically update the taxonomic resolution listed in Table 2. This will necessitate an updating of historical data to the new taxonomic resolution so that temporal comparisons of water quality at sites can continue using the same taxonomic standard.

e) Water Quality Assessment:

Various methods are available to interprete benthic data in terms of water quality, depending upon the specific question and extent (spatial and temporal) of the data. When only a

limited amount of data is analyzed, however, time series analyses and multivariate analyses are generally not appropriate. Water quality "metrics" thus are the principle means of summarizing taxonomic data for water quality analysis and interpretation, particularly for annual reports. The ten metrics utilized in BioMAP include:

1) Total Numbers - the total number of organisms in a sample;
2) Taxa Richness - the number of taxa present in a sample (alpha richness) or at a site (gamma richness);
3) EPT Richness - the number of mayfly, stonefly and caddisfly taxa in a sample;
4) Ratio of Chironomids to Insects - the total number of chironomids as a proportion of the total number of insects in a sample;
5) Ratio of Oligochaetes to Total Numbers - the total number of oligochaetes as a proportion of the total number of organisms in a sample;
6) Ratio of Scrapers to Filtering Collectors - the total number of scrapers as a proportion of the total number of filtering collectors in a sample. The functional-feeding group designations for insects are based primarily on Merritt and Cummins (1984);
7) Ratio of Shredders to Total Numbers - the total number of shredders as a proportion of the total number of organisms in a sample;
8) Taxonomic Composition - the proportion of insects, crustaceans, snails, bivalves, leeches, worms, and flatworms in a sample;
9) BioMAP Water Quality Index - an abundance-weighted pollution tolerance measure. The Water Quality Index (WQI) is based on pollution tolerance values assigned to macroinvertebrate taxa. A list of pollution-tolerance values for lotic macroinvertebrates occurring in Ontario is presently being compiled (Griffiths, unpublished data) and will be available later, along with the details of the WQI, in a future BioMAP document. The pollution-tolerance values assigned to macroinvertebrates vary from 0 to 4, with 4 denoting that a taxon is sensitive to anthroprogenic stresses (i.e. taxa sensitive to increases in nutrients, organics, suspended sediments, temperature, altered flows, etc.), and 0 meaning that a taxon is tolerant to anthroprogenic stresses. The index is similar to those developed by Hilsenhoff (1982, 1988), Cook (1976), Chutter (1972), and Chandler (1970).
10) Characterizing Species - a list the characteristic or indicator species observed at the site. The environmental tolerances and habitat requirements of a large number of species is well documented. Thus characterizing species can convey substantial amounts of information because of their presence at a site. For example:

i) a site characterized by Limnodrilus hoffmeisteri and Tubifex tubifex is typical of an organically enriched, low oxygenated, warm-water river with depositional habitat characteristics;

ii) a site characterized by Prodiamesa is typical of an organically enriched, cold, fast-flowing stream;

iii) a site characterized by Nemourid stoneflies, Baetis tricaudatus and Glossosoma is typical of an unimpaired, spring-fed, fast-flowing, cold-water stream with an enclosed riparian canopy.

Water quality at each site is classified as unimpaired (site supports native species characteristic of habitat) or impaired (native species characteristic of habitat are replaced with more pollution-tolerant species). The assessment is based on the water quality metrics, field observations and measurements, and possibly other data (e.g. water chemistry). In much the same way as a doctor measures the pulse, blood pressure and temperature, listens to the heart beat and breathing, looks into the throat and ears, samples blood and urine of a patient before making a prognosis (healthy, sick), an aquatic ecologist measures a number of variables, observes characteristics and samples components of the stream before making a water quality prognosis (unimpaired, impaired). Values of each metric representing unimpaired (healthy) and impaired water quality conditions are presently be compiled from data collected over the past decade and will be available later in a future BioMAP document. Some BioMAP benchmark sites representing reference (unimpaired) conditions will help fine tune the values of each metric representing unipaired conditions as data become available. Since the metric values change in a predictable fashion from headwaters to the mouth of riverine systems and thus are dependent on stream size and location within the drainage basin, stream width under bankfull conditions is used as the main scaling variable to interpret (translate) metric values into terms of water quality.

Unimpaired water quality sites are subsequently classified as robust or sensitive. Sites classified as robust are characterized by a benthic fauna that is diverse in species and functionally redundant (many species in each functional-feeding group). These sites recover quickly from natural disturbances (hot summers, drought, flooding, etc.) and tolerate infrequent anthropogenic stresses. In contrast, sites classified as sensitive are characterized by a benthic fauna that is poor in species richness, contains a high proportion of pollution-intolerant species and functional simple. These sites may reflect unique natural habitats that depend almost exclusively on a single source of food or a narrow range of enironmental conditions (e.g. cold-water springs), or habitats that appear unimpaired but are actually tolerating (assimulating) a degree of stress. These sites are

highly suseptable to anthropogenic stresses and may require a long period of time to recover from natural disturbances. Unimpaired sites are relatively rare throughout most of southwestern Ontario.

Impaired water quality sites are subsequently classified by the primary causal stress: For example, enriched sites are those impaired by organic or nutrient discharges; degraded sites are those impaired through physical habitat alterations (temperature, flow, channelization, etc.); and toxic sites are those impaired by chemical pollution. Griffiths (1991) provides an example of water quality classifications.

In addition to classifying water quality as unimpaired or impaired, an effort is made to interpret changes in values of the metrics over time in terms of improving or degrading water quality. Water quality conditions are considered to show improvement when a majority of the metrics show a shift towards those values that are considered to represent "unimpaired conditions". When the reverse is true, water quality conditions are considered to be degrading.

Further discussions of data analysis techniques and concepts can be found in EC (1991b), Karr (1991), Klemm et al. (1990), Plafkin et al (1989).

f) Data Storage:

After the macroinvertebrates are identified, the benthic samples and BioSurvey Cards are archived together in storage cabinets. The taxonomic data from the BioSurvey Cards are entered and stored as a spreadsheet file (Microsoft Excel). Individual files are created for the samping sites and data for each benthic sample are placed in a single column. A summary file for each sampling site then is created that stores the values for the 10 metrics noted above.

A meta-file for each site is also created. Meta-files contain data about the benthic data. These files include: sampling date, type of sampling equipment used, area sampled, habitat sampled, mesh size of collecting equipment, preservative used, sorting technique, mesh size of laboratory equipment, taxonomist, etc. With a standardized protocol in place, data in meta-files are similar from site to site and year to year. It is the deviations from standard methods, however, that are the important pieces of information when benthic data are compared and analyzed.

The completed Benthic Survey Field Notes sheet, on which the field observations and measurements are recorded, are filed by sampling site. A scanner is used to make a digital copy of these notes, which are stored in a "Site Folder" on disk. Colour slides of the site are labelled, placed in plastic holders and filed with the Field Notes. In addition a digital copy of the slides are placed in the Site Folder. The original video footage of each site is kept; in addition, 3-5 minutes of video showing the main characteristics of the sampling site, location of samples, land-use, etc. is digitally captured and placed into the Site Folder. All computer files are stored on optical disks.

g) Reporting:

Results from BioMAP are published in four types of written reports:

1) Annual Summary,
2) Water Quality Assessment,
3) Research,
4) Program.

The Annual Summary report is produced about 6 months after year end. Values of the ten metrics for the Benchmark, Early Warning and Reclamation stations form the data base of the report. The report provides:

i) water quality classifications of the sites;
ii) indications of water quality impairment among the early warning sites;
iii) indications of water quality improvement among the reclamation sites.

The benthic data, field observations and other information are not included in the report, but are available upon request. In this way, the Annual Summary reports are concise and brief; they are not an extensive, detailed assessment of all available data.

Water Quality Assessment reports report the results of Special Studies. Typically, these studies examine the effect of point and non-point source discharges on the water quality of riverine systems. In addition to sampling benthos, they may sample water or sediment for bacterial and chemical analyses, or sample other biota (e.g. algae, macrophytes, fish) depending on the specific question of interest. Generally, the data are collected during a single sampling period, upstream and downstream of identified discharge points or areas.

Research reports provide information on advancements in ecological theory, benthic taxonomy, sampling methods and designs, techniques and methods of analysis, etc. that assist with water quality evaluations of aquatic systems.

Program reports, such as this one, provide an up-to-date summary and overview of the concepts, protocols and sampling procedures of BioMAP.

In addition to written reports, results of some BioMAP activities are published in digital formats. Digital reporting combines information expressed in different types of media (e.g. audio, video, graphics, maps, animation, text) into a slide show or movie format. Digital reports generally report on BioMAP sampling methods, the results of Special Studies (in addition to the Water Quality Assessment Reports), or specific Research Items (e.g. benthic taxonomy). Although not generally available, digital Site Reports are maintained and continuously updated for each of the benchmark, early warning and reclamation sampling sites. Digital reports are available on disc (MacIntosh) or VHS tape.

In addition, all data and field observations (e.g. video, slides, benthos, chemistry, bacteria) are linked to a Georeferenced Data Retrieval System. Using "push button technology" users can find out what information is available for any stream in the southwestern region of Ontario. This system will not be fully functional until 1995.

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Table 1: Location of Benchmark, Early Warning and Reclamation sites established in 1993. UTMs were obtained using a Magellan 5000 global positioning unit; those marked with an * were obtained from topological maps.

BENCHMARK SITES:

River	Description of Site Location	UTMs
1. Albemarle Creek	Bruce County - Albemarle Twsp.	N 4 964 535
	Upstream of Hwy 6 Bridge	E 482 672
2. Rocky Saugeen	Grey County - Artemesia Twsp.	N 4 908 829
	Downstream of old bridge on Twsp line	E 528 133
	North of Markdale	
3. Sucker Creek	Grey County - St. Vincent Twsp.	N 4 950 350
	Downstream of County Rd 20 Bridge	E 521 800 *
	Canadian Forces Training Area - Meaford	
4. Beaver River	Grey County - Osprey Twsp.	N 4 906 200
	Bridge on Osprey-Artemesia Twsp road	E 543 900 *
	East of Lake Eugenia	
5. Big Otter Creek	Oxford County - South Norwich Twsp.	N 4 749 440
	Downstream of Concession 10 Bridge	E 531 193
	South of Otterville	
6. Belgrave Creek	Huron County - East Wawanosh Twsp.	N 4 851 730
	Downstream of Bridge, located 3 side roads	E 464 195
	West of Hwy 4, near Concession 6-7.	
7. Washington Creek	Oxford County - Blenhiem Twsp	N 4 797 835
	Upstream of Concession 14 Bridge	E 532 415
	Northwest of Washington	
8. Thames River	Middlesex County - North Dorchester Twsp	N 4 758 637
	Upstream of County Road 25 Bridge	E 490 875
	North of Nilestown	
9. Sydenham River	Lambton County - Brooke Twsh.	N 4 739 416
	Upstream of Hwy 80 Bridge	E 430 749
	Southwest of Alvinston	
10. Ruscom River	Essex County - Rochester Twsh	N 4 674 338
	Under County Road 46 Bridge	E 365 520

Table 1: continued.

EARLY WARNING SITES:

River	Description of Site Location	UTMs
1. Dutton Creek	Elgin County; Dunwich Twsp.	N 4 718 714
	Downstream of Highway 3 Bridge	E 460 265
2. Waubuno Creek	Middlesex County; North Dorchester Twsp.	N 4 758 291
	Upstream of River Road Bridge	E 489 253
	East of Hwy. 100	
3. South Saugeen River	Grey County; Egermont Twsp.	N 4 869 670
	Upstream of Hwy 89	E 522 840
	East of reservior at Mt. Forest	
4. Lucknow River	Lucknow	N 4 868 140
	Downstream of Ludgard Street Bridge	E 458 927
5. Trick's Creek	Huron County; Goderich Twsp.	N 4 826 900
	Upstream of County Rd 13 Bridge	E 453 050
	West of Clinton	
6. Dingman Creek	City of London	N 4 750 575
	Upstream of Dingman Rd. Bridge	E 478 445
7. Pottawattawi River	Grey County; Derby Twsp	N 4 933 995
	East of Maxwell Cr. Confluence	E 501 853
	East of Springmount	
8. Silver Creek	Grey County; Collingwood Twsp.	N 4 926 060
	Upstream of County Rd 19 Bridge	E 556 967
9. Spey River	Grey County; Holland Twsp	N 4 921 072
	South of Chatsworth	E 509 877
10. Boyne River	Grey County; Artemesia Twsp.	N 4 902 986
	Upstream of Concession 3 East Bridge	E 536 358
	Northeast of Flesherton	

Table 1: continued.

RECLAMATION SITES:

River	Description of Site Location	UTMs
1. Thames River	City of London	N 4 756 650
	Downstream of Byron Bridge	E 472 950 *
2. Maitland River	Perth County; Elma Twsp	N 4 842 286
	Upstream of Concession 1-2 Bridge	E 499 240
	East of Listowel	
3. North Thames River	City of London	N 4 765 350
	Upstream of Clarke Side Road Bridge	E 484 370
	Downstream of Fanshawe Dam	
4. Little River	City of Windsor	N 4 684 419
	Upstream of Forest Glen Road Bridge	E 341 325
5. Black Creek	Lambton County; Enniskillen Twsp.	N 4 738 344
	Upstream of Bridge	E 406 855
	West of Oils Springs	
6. Kettle Creek	Elgin County; Yarmouth Twsp.	N 4 741 380
	Upstream of County Rd 30 Bridge	E 487 761
	Northeast of St. Thomas	
7. Avon River	City of Stratford	N 4 802 557
	East end of Golf Course	E 504 211
8. Middle Thames River	Oxford County; North Oxford Twsp.	N 4 766 107
	South of Thamesford	E 500 271
9. Pottersburg Creek	City of London	N 4 758 159
	Downstream of Gore Road Bridge	E 485 753
10. Maxwell Creek	Grey County; Derby Twsp	N 4 933 481
	Upstream from Hwy 6 Bridge	E 501 690
	Southeast of Springmount	

Table 2: BioMAP's required taxonomic resolution and primary taxonomic references for the identification of macroinvertebrates from southwestern Ontario. Note: only late instars (nymphs) or adults can be identified to species; younger individuals typically can only be identified to genus.

Taxon	Required Taxonomic Resolution	Primary Taxonomic Reference *
A. INSECTS	Genus	Merritt & Cummins 1984
1. Beetles	Genus	Merritt & Cummins 1984
a. Elmidae	Species (adults)	Hilsenhoff & Schmude 1992
		Brown 1972
2. Caddisflies	Genus	Wiggins 1977
3. Dragonflies	Species	Walker & Corbet 1978
		Walker 1958
4. Mayflies	Genus	Edmunds et al. 1976
a. Baetidae	Genus	McCafferty & Walz 1990
b. Baetis	Species	McCafferty & Walz 1990
		Morihara & McCafferty 1979
c. Ephemerella	Species	Allen & Edmunds 1965
d. Ephemeridae	Species	McCafferty 1975
e. Eurylophella	Species	Allen & Edmunds 1963
f. Stenonema	Species	Bednarik & McCafferty 1979
5. Stoneflies	Genus	Stewart & Stark 1988
a. Isoperla	Species	Hitchcock 1974
b. Leuctridae	Species	Harper & Hynes 1971a
c. Nemouridae	Species	Harper & Hynes 1971b
d. Perlidae	Species	Hitchcock 1974
6. True Flies	Genus	Merritt & Cummins 1984
a. Chironomidae	Genus	Wiederholm 1983

Table 2: continued.

Taxon	Required Taxonomic Resolution	Primary Taxonomic Reference *
B. CRUSTACEANS	Genus	Pennak 1989
1. Amphipods	Genus	Bousfield 1967
a. Gammarus	Species	Holsinger 1976
		Bousfield 1967
2. Crayfishes	Species	Crocker & Barr 1968
C. MOLLUSCS	Genus	Burch 1989
		Clarke 1981
D. ANNELIDS	Species	Brinkhurst 1986
		Klemm 1985
E. FLATWORMS	Order	Pennak 1989

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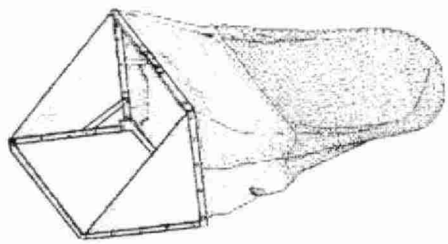
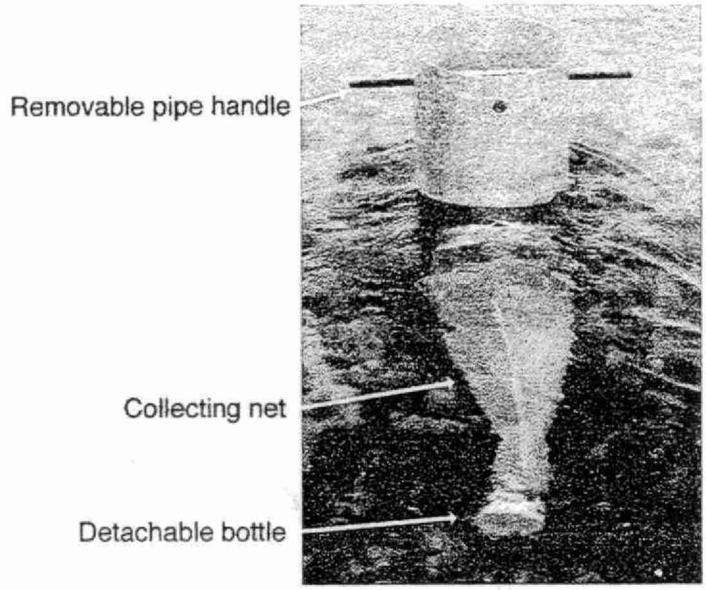
Figure 1:
Distribution of BioMAP sites throughout southwestern Ontario. Numbers refer to sites listed in Table 1.

Figure 2: Types of Benthic Samplers.



Surber Sampler



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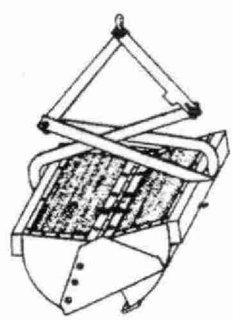
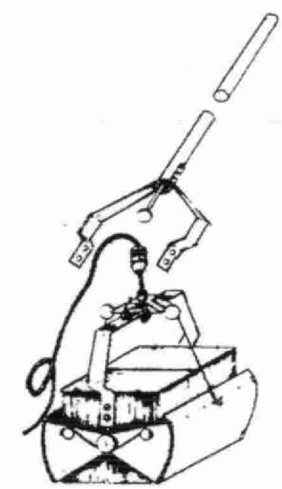


Ponar Sampler



Ekman Sampler

D-Frame Net

Figure 3: Sample BioSurvey Card that is completed for each benthic sample.

Ministry of the Environment and Energy

BioSurvey Card

Sampling Date

__________ 19____

Survey______________________________Station____________Sample__________

Location__________________________________No. of Bottles______________

Description of Station____

Notes____

Collecting Method____

General Group	#	Taxon	#	Taxon	#

front

back

General Group	#	Taxon	#	Taxon	#

Notes:

Collected by__________________________Identified by______________________

Figure 4: Sample of Benthic Survey Field Notes sheet that is completed at each site. General site characteristics are recorded on the front of the page, while specific characteristics of each benthic sample are recorded on the back of the page.

front of page

Ministry of the Environment
Water Resources Assessment Unit
985 Adelaide Street South
London, Ontario N6E 1V3

BENTHIC SURVEY FIELD NOTES

SURVEY: ______________________________ DATE: ______________

BODY OF WATER: ______________________________ STATION: ______________

LOCATION: ____

SAMPLING EQUIPMENT: ____

OTHER SAMPLES COLLECTED: ____

COMMENTS: ____

Site Characteristics:

Stream width __________ Depth __________ Substrate ______________________

Water Clarity ____________________ Odour ______________________

Macrophytes ____________________ Algae ______________________

Bank Vegetation ____________________ Land Use ______________________

General ____

____

____

____

Map: ____

(Show North)

Sampling Site	Water Temp.	Dis. Oxygen	pH	Conductivity	Water color	Current

(over)

Figure 4: continued.

back of page

1) Location: ______________________________

Depth: __________ Sampler Fullness: __________ Sample Bottles: __________

Sediment Type: ____________________ Odour: __________

Sediment Characteristics: ______________________________

Macrophytes: none sparce common abundant ____________________

Algae: none sparce common abundant ____________________

Invertebrates: ______________________________

Notes: ______________________________

2) Location: ______________________________

Depth: __________ Sampler Fullness: __________ Sample Bottles: __________

Sediment Type: ____________________ Odour: __________

Sediment Characteristics: ______________________________

Macrophytes: none sparce common abundant ____________________

Algae: none sparce common abundant ____________________

Invertebrates: ______________________________

Notes: ______________________________

3) Location: ______________________________

Depth: __________ Sampler Fullness: __________ Sample Bottles: __________

Sediment Type: ____________________ Odour: __________

Sediment Characteristics: ______________________________

Macrophytes: none sparce common abundant ____________________

Algae: none sparce common abundant ____________________

Invertebrates: ______________________________

Notes: ______________________________

Addition Information: ______________________________

Collector: ____________________ Notes By: ____________________